LA-UR-08-0594

THREE-DIMENSIONAL SIMULATION OF KEV-PHOTON LASER OPERATION USING GEV ULTRA-SHORT LASER-GENERATED ELECTRON BUNCHES*

Mark J. Schmitt, William S. Daughton, Lin Yin, Brian J. Albright, Daniel S. Main and Thomas J.T. Kwan
Los Alamos National Laboratory, MS F699, Los Alamos, NM 87545 USA

The recent discovery of electron bunch acceleration to GeV energies using ultra-short laser pulses propagating through centimeter-scale plasmas[1] has stimulated interest in the use of these "mono-energetic" electron bunches to drive Self-Amplified Spontaneous Emission (SASE) free-electron lasers (FELs). Theoretically, one can generate 0.1-1 KeV coherent FEL photon pulses provided an electron bunch having high peak current, concomitant with low emittance and energy spread, can be achieved and successfully injected into the FEL wiggler.

We have simulated the bubble acceleration of electrons using the 3-D particle-in-cell (PIC) code VPIC[2]. The VPIC code has recently been optimized for the Roadrunner computer platform[3] facilitating simulation of the entire acceleration process in the laboratory frame in 3-D. The electron distribution from these VPIC simulations is used as input for the 3-D FEL code FELEX[4] to calculate the self-consistent growth from spontaneous emission of the 0.1-1 KeV photon pulse produced in the wiggler. FELEX models the interaction of the electron pulse with the optical pulse including the transverse dependences of the wiggler field (including wiggler field errors, if desired), and the transverse fall off of the electron density and optical field intensity. Examples of these simulation will be shown including the effects of electron beam quality on FEL extraction efficiency. These calculations provide an initial estimate of the specifications for both the electron acceleration quality and the FEL wiggler design parameters.

1. W. P. Leemans, B. Nagler, A. J. Gonsalves, Cs. Tóth, K. Nakamura, C. G. R. Geddes, E. Esarey, C. B. Schroeder, S. M. Hooker, "GeV electron beams from a centimeter-scale accelerator", Nature Physics **2**, pp. 696-699 Oct. 1, 2006.
2. K. J. Bowers, "Speed optimal implementation of a fully relativistic charge conserving current accumulation on modern processors", Los Alamos National Laboratory Report LA-UR-03-3359, 2003.
3. K. J. Bowers, "Toward Petaflop First Principles Kinetic Plasma Simulation", 49th Amer. Phys. Soc. Meeting of the Div. of Plasma Physics, Nov 12-16, 2007.
4. B. D. McVey, "Three Dimensional Simulations of Free Electron Laser Physics", Nuc. Instr. Meth. Phys. Res. **A250**, 1986, pp. 449-455

* Work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396